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(54) **SYSTEM FOR REDUCING A FOOTPRINT OF AN ULTRASOUND TRANSDUCER PROBE**

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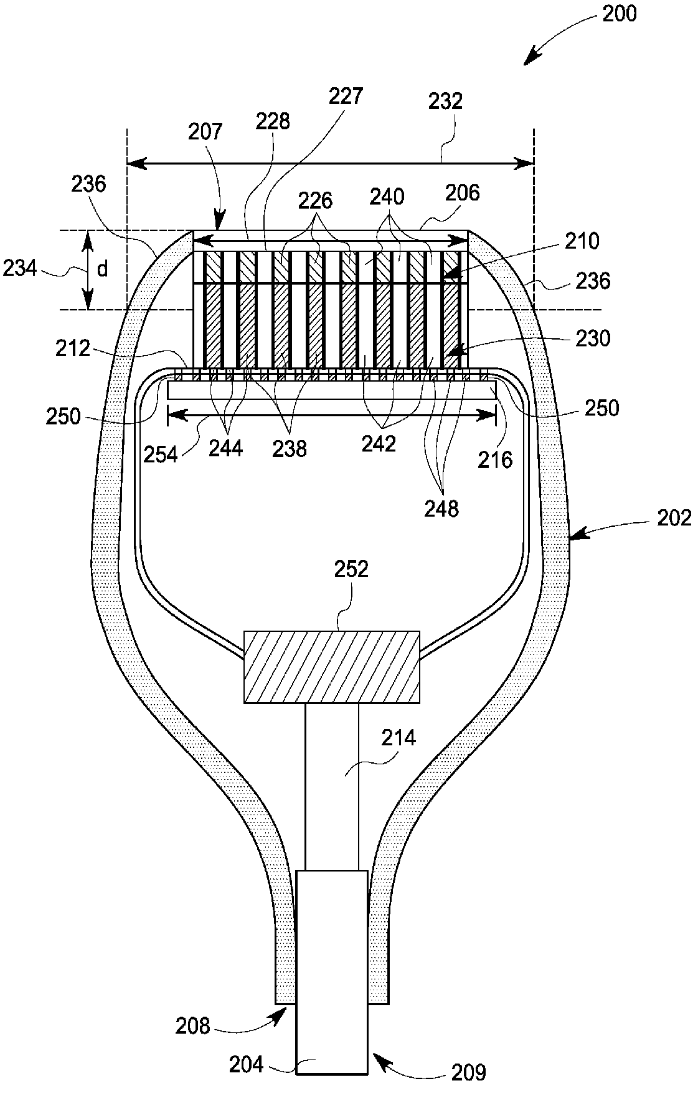
(57) **ABSTRACT**

A transducer probe is presented. The transducer probe includes a housing having a probe surface at a first end. Further, the transducer probe includes an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume. Also, the transducer probe includes a flex interconnect configured to electrically couple the acoustic array to at least one electronic unit. Furthermore, the transducer probe includes an electrical standoff disposed between the acoustic array and the flex interconnect to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array aperture.



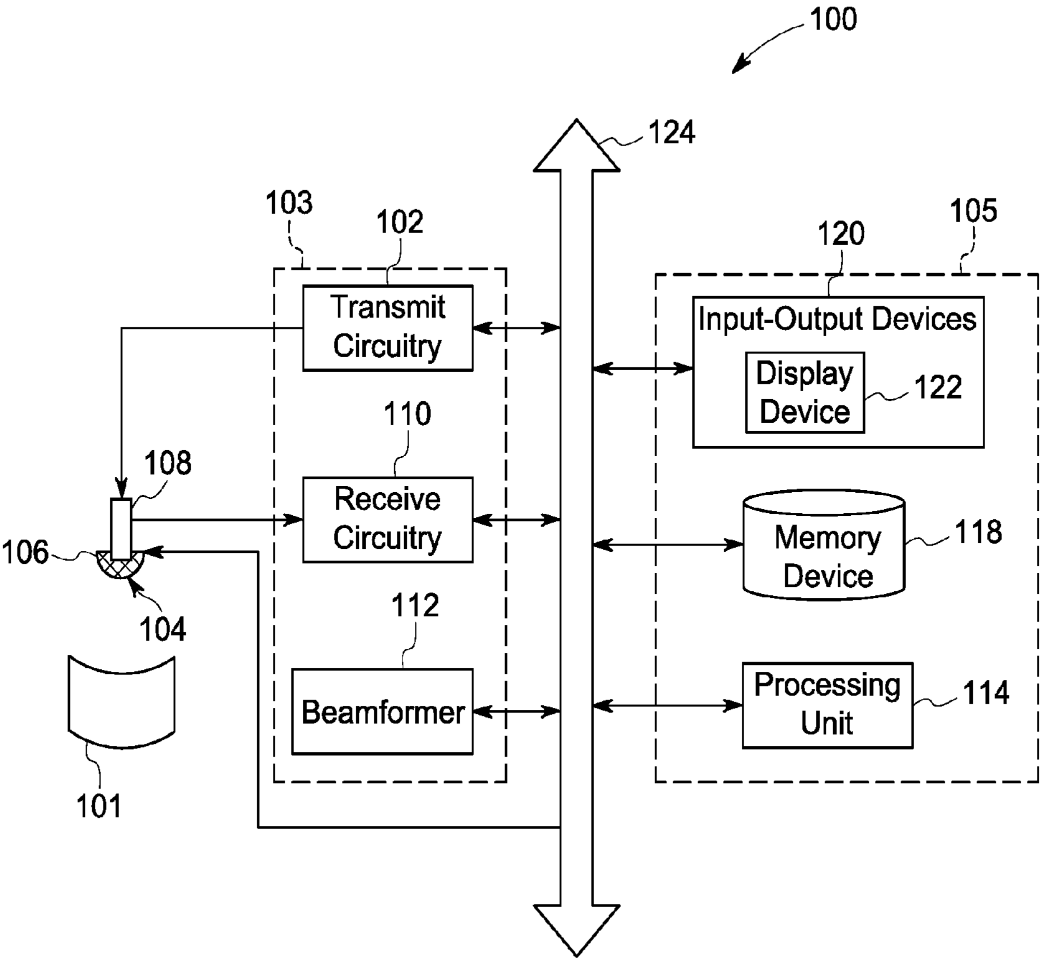

100
124
103
102
Transmit Circuitry
110
Receive Circuitry
112
Beamformer
108
106
104
101
105
120
Input-Output Devices
Display Device
122
Memory Device
118
Processing Unit
114

FIG. 1

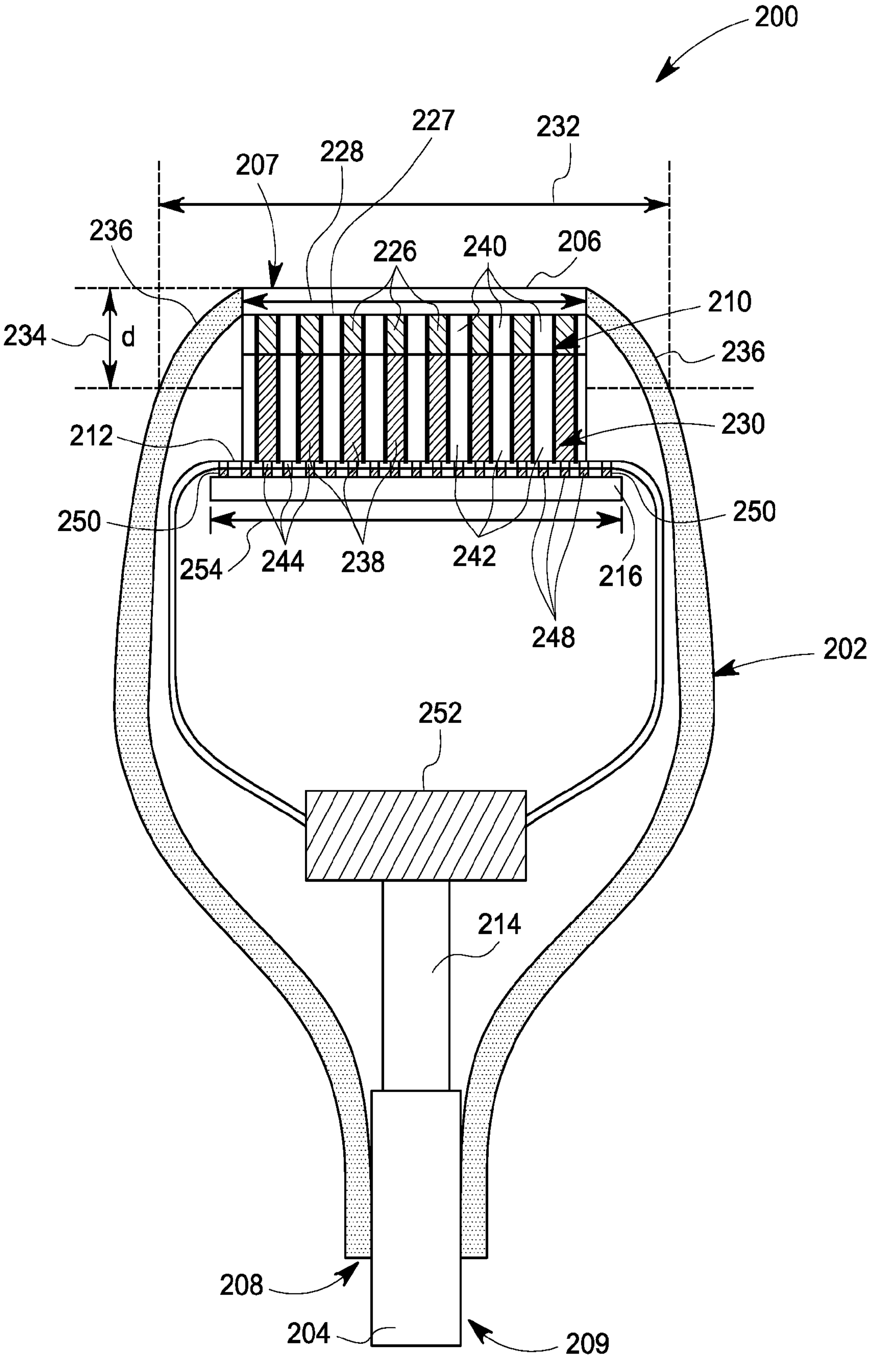

200
227
232
207
228
236
226
240
206
210
234
d
236
230
212
250
250
254
244
238
242
216
248
202
252
214
208
204
209

FIG. 2

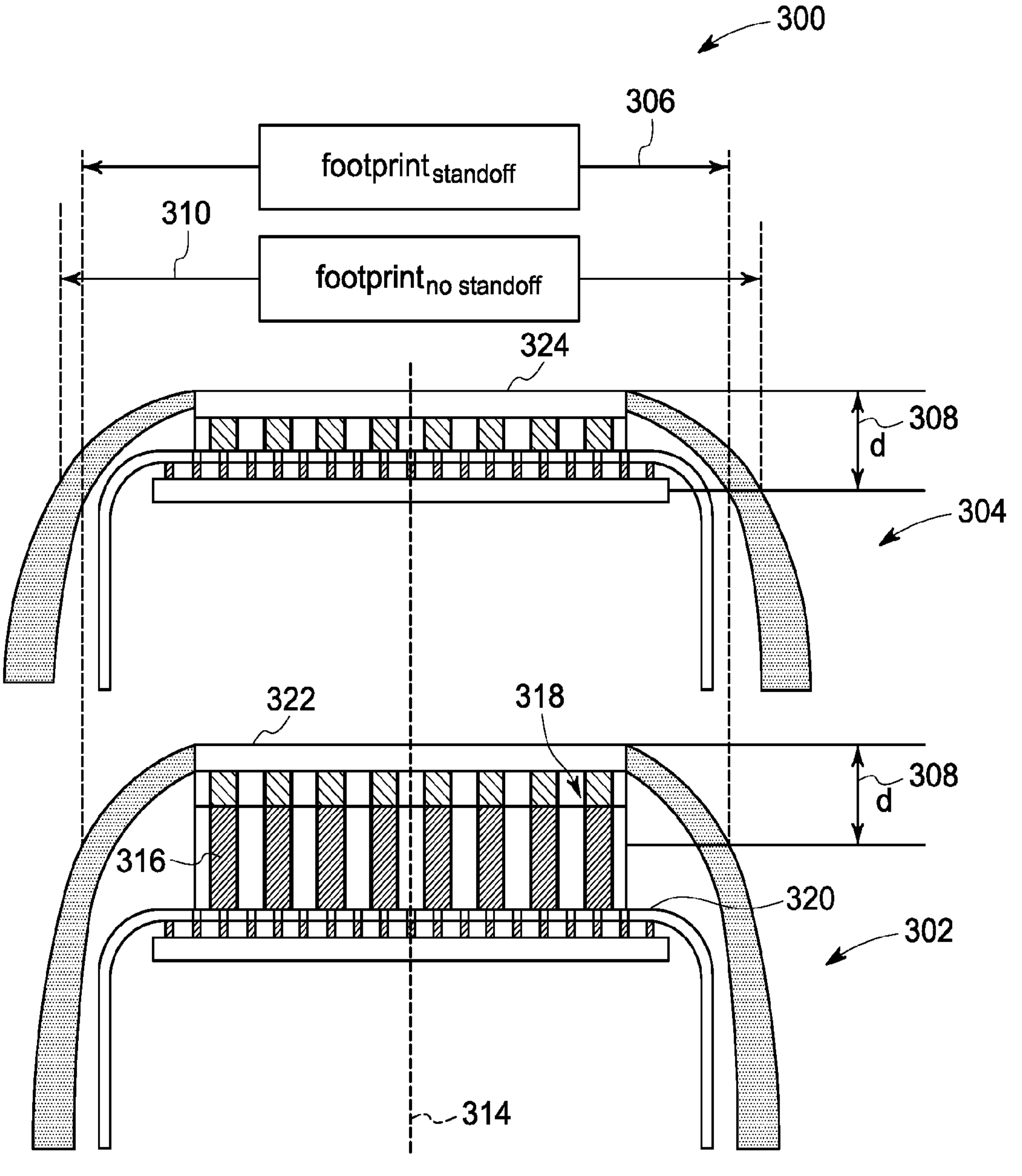

300
306
$\text{footprint}_{\text{standoff}}$
310
$\text{footprint}_{\text{no standoff}}$
324
308
d
304
322
318
308
d
316
320
302
314

FIG. 3

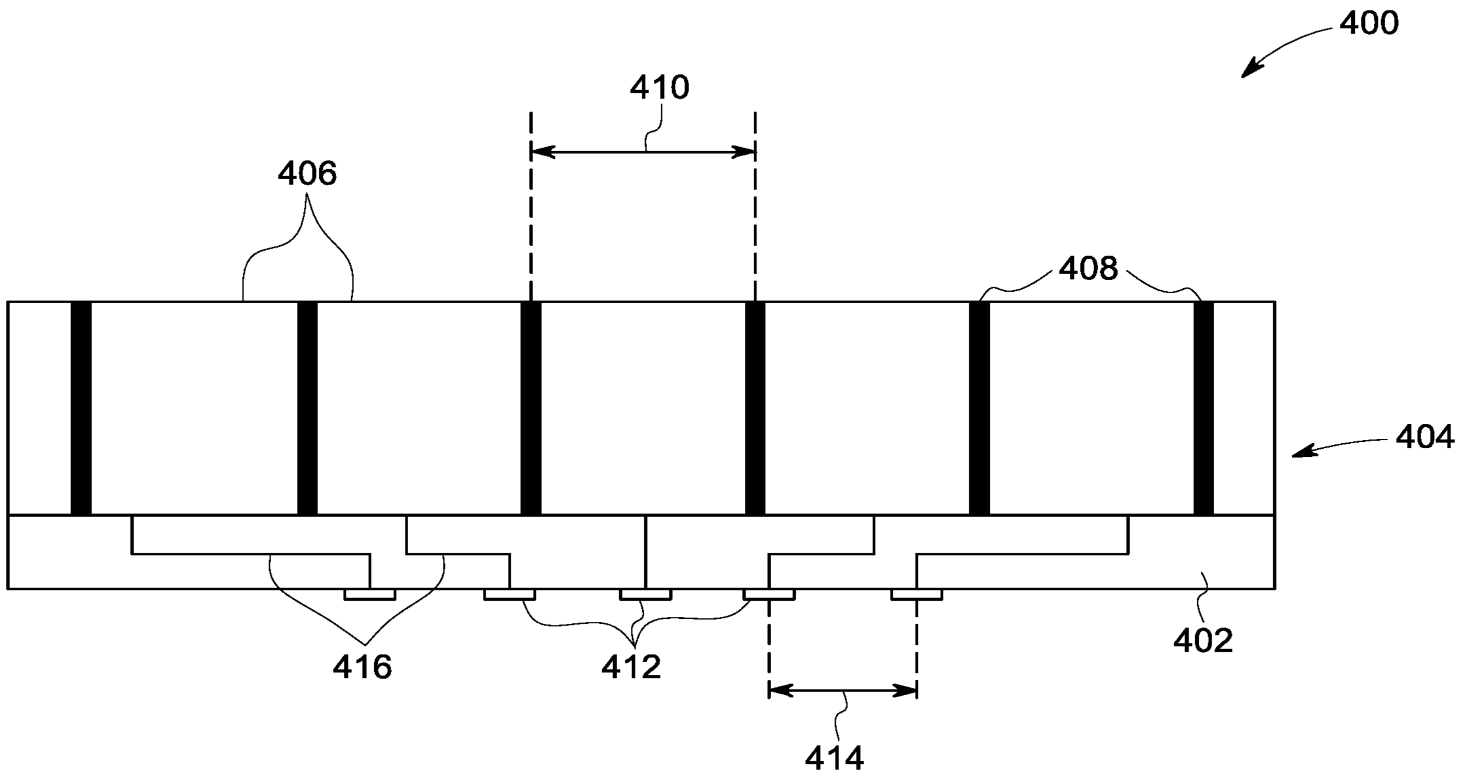


FIG. 4

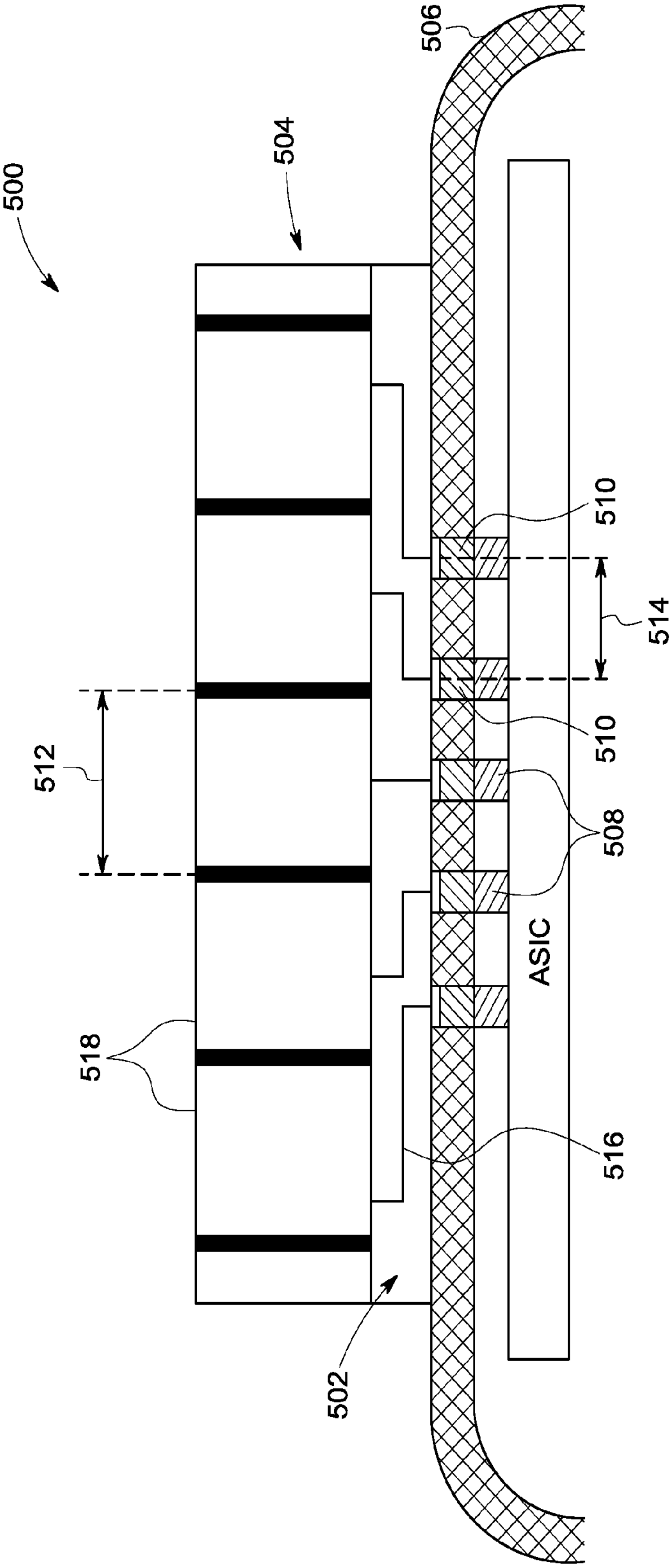


FIG. 5

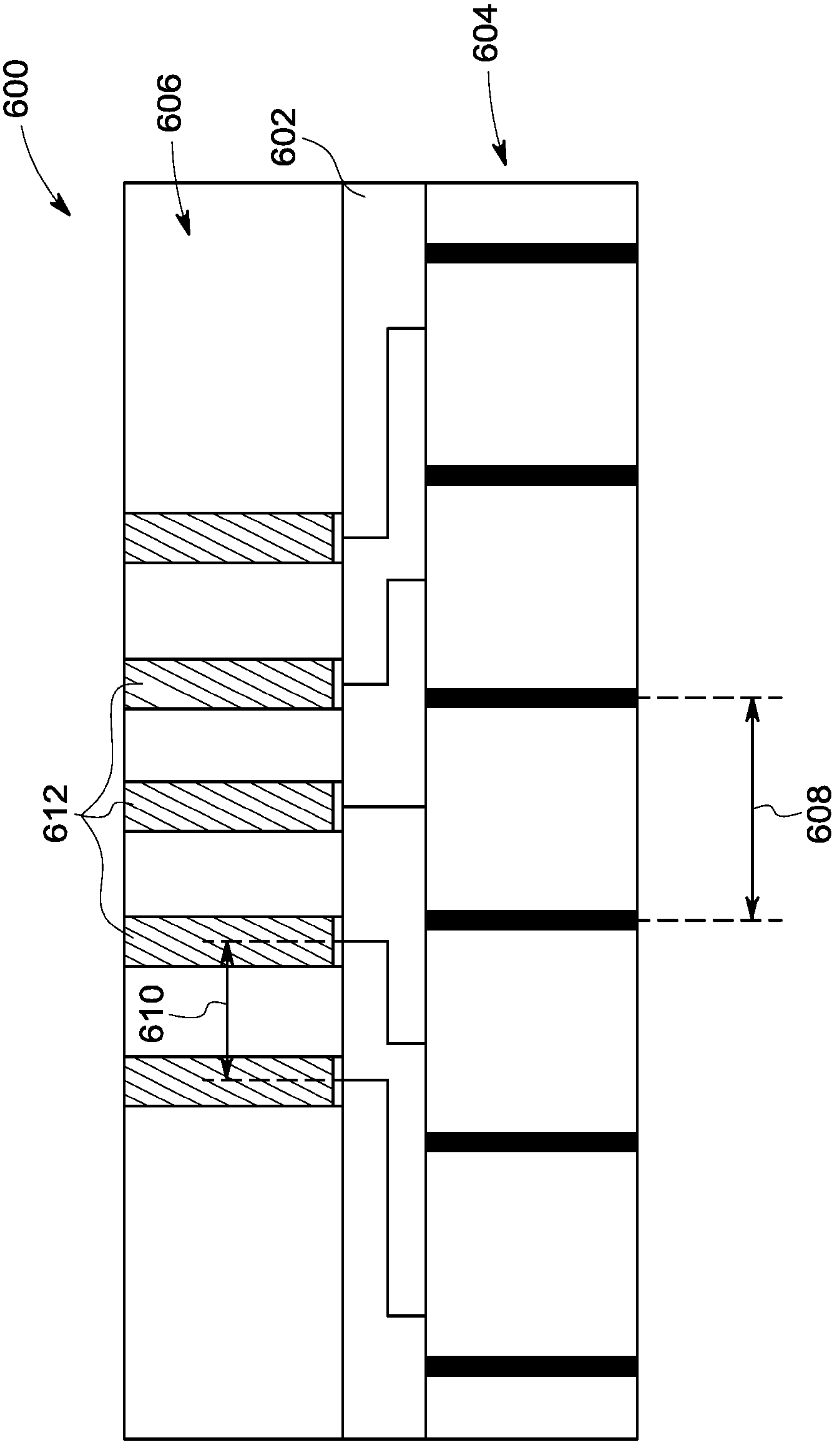


FIG. 6

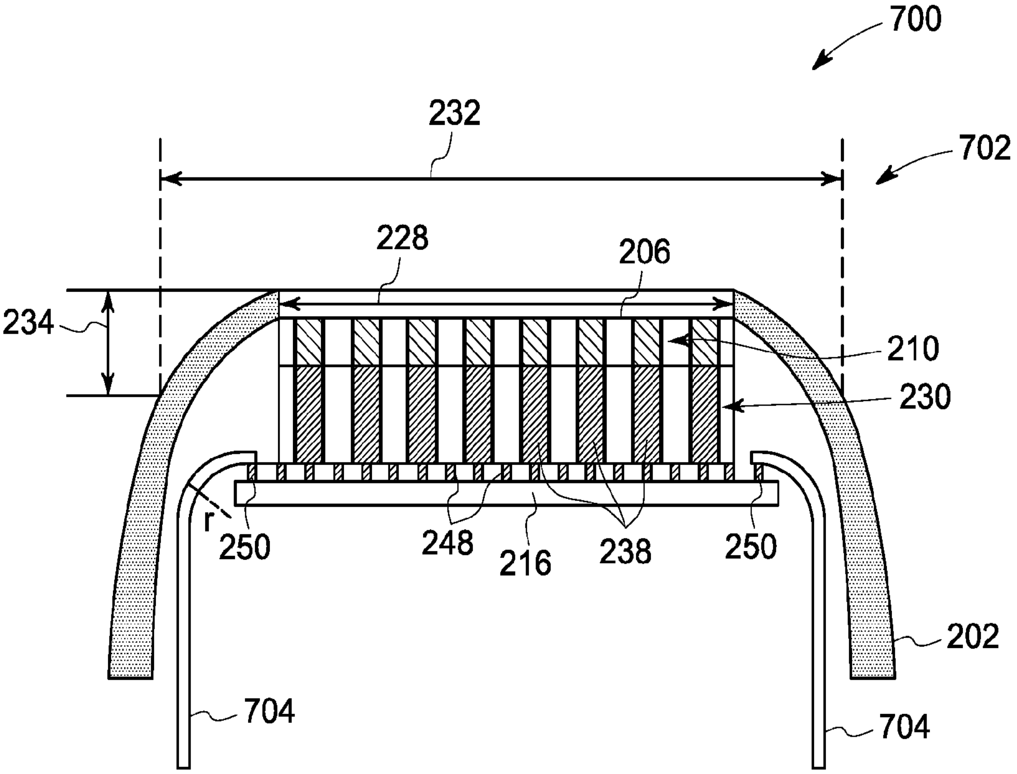

700
702
232
228
206
234
210
230
r
250
248
216
238
250
202
704
704

FIG. 7

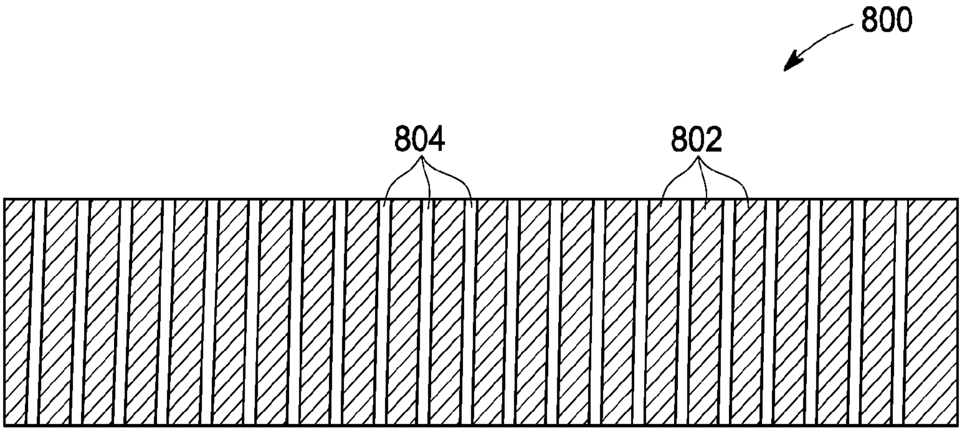

800
804
802

FIG. 8

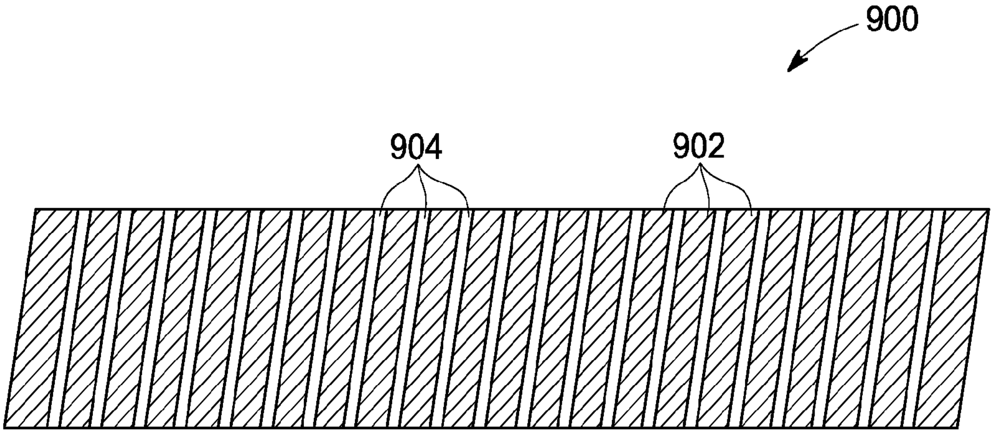


FIG. 9

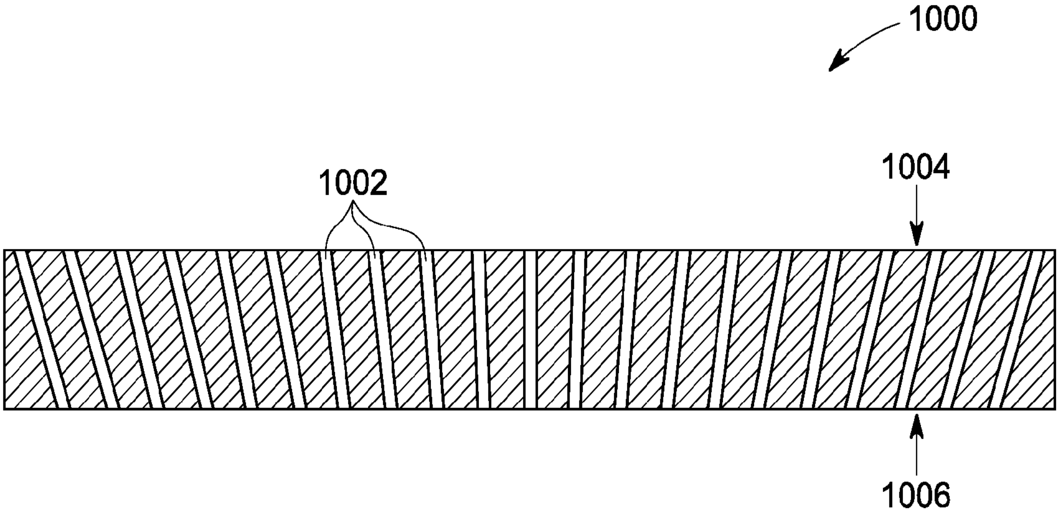


FIG. 10

SYSTEM FOR REDUCING A FOOTPRINT OF AN ULTRASOUND TRANSDUCER PROBE

BACKGROUND

[0001] Embodiments of the present specification relate generally to an ultrasound transducer probe, and more particularly to a system for reducing a footprint of the ultrasound transducer probe.

[0002] Medical diagnostic ultrasound is an imaging modality that employs ultrasound waves to probe acoustic properties of biological tissues and produces corresponding images. Particularly, ultrasound systems are used to provide an accurate visualization of muscles, tendons, and other internal organs to assess their size, structure, movement, and/or pathological conditions using near real-time images. Moreover, owing to the ability to image underlying tissues without use of ionizing radiation, ultrasound systems find extensive use in angiography and prenatal scanning.

[0003] Conventional ultrasound systems employ various components, such as a transducer probe that houses an acoustic stack, an interconnect, and an application specific integrated circuit (ASIC). These components are used to transmit and receive ultrasound signals from a target volume in a patient or a subject. However, in these systems, a lateral size of the ASIC and a lateral size of the interconnect are substantially larger than a lateral size of the acoustic stack in the transducer probe. As a result, a footprint of the transducer probe extends beyond the lateral size of the acoustic stack. As will be appreciated, while scanning, transducer probes with smaller footprints are relatively easier to maneuver. By way of example, a transducer probe, such as a transthoracic probe, needs to be positioned in small acoustic windows available between ribs of the patient for cardiac imaging. However, it is difficult to position a conventional transducer probe in these small windows due to the large footprint of the transducer probe.

BRIEF DESCRIPTION

[0004] In accordance with aspects of the present specification, a transducer probe is presented. The transducer probe includes a housing having a probe surface at a first end. Further, the transducer probe includes an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume. Also, the transducer probe includes a flex interconnect configured to electrically couple the acoustic array to at least one electronic unit. Furthermore, the transducer probe includes an electrical standoff disposed between the acoustic array and the flex interconnect to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array aperture.

[0005] In accordance with a further aspect of the present specification, a system for ultrasound imaging is presented. The system includes an acquisition subsystem configured to obtain image data corresponding to a target volume in an object of interest and including an ultrasound probe, wherein the ultrasound probe includes a housing having a first end and a second end, wherein the first end includes a probe surface, and wherein the second end is coupled to a probe cable, an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume, a flex interconnect configured to electrically couple the acoustic array to at least one electronic unit, and an electrical standoff disposed between the acoustic array and the flex interconnect to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array aperture. Further, the system includes a processing subsystem in operative association with the acquisition subsystem and configured to process the acquired image data to generate one or more images corresponding to the target volume in the object of interest.

[0006] In accordance with another aspect of the present specification, a transducer probe is presented. The transducer probe includes a housing having a probe surface at a first end. Further, the transducer probe includes an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume. Also, the transducer probe includes at least one ASIC configured to electrically couple the acoustic array and configured to receive the ultrasound signals reflected from the target volume. In addition, the transducer probe includes an electrical standoff disposed between the acoustic array and the at least one ASIC to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array.

DRAWINGS

[0007] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. **1** illustrates an ultrasound system for imaging a target volume in a subject, in accordance with aspects of the present specification;

[0009] FIG. **2** is a diagrammatical representation of a transducer probe having an electrical standoff and a flex interconnect, in accordance with aspects of the present specification;

[0010] FIG. **3** is a diagrammatical representation of a comparison of an exemplary transducer probe with a conventional transducer probe, in accordance with aspects of the present specification;

[0011] FIG. **4** is a diagrammatical representation of a first interposer coupled to an electrical standoff, in accordance with aspects of the present specification;

[0012] FIG. **5** is a diagrammatical representation of a first interposer coupled to an electrical standoff and having a flex interconnect positioned between the electrical standoff and ASIC bumps, in accordance with aspects of the present specification;

[0013] FIG. **6** is a diagrammatical representation of a second interposer coupled to an electrical standoff, in accordance with aspects of the present specification;

[0014] FIG. **7** is a diagrammatical representation of a portion of an exemplary transducer probe having an electrical standoff, in accordance with aspects of the present specification; and

[0015] FIGS. **8-10** are diagrammatical representations of different embodiments of an electrical standoff, in accordance with aspects of the present specification.

DETAILED DESCRIPTION

[0016] As will be described in detail hereinafter, various embodiments of an ultrasound transducer probe for reducing a footprint of the ultrasound transducer probe are presented. In particular, the ultrasound transducer probe and methods presented herein employ an electrical standoff to reduce the footprint of the ultrasound transducer probe. In addition to reducing the footprint of the transducer probe, the electrical standoff may also be used to attenuate ultrasound signals emitted from an acoustic array towards a flex interconnect disposed in the transducer probe. Further, the electrical standoff may be used to manage heat generated in the ultrasound transducer probe.

[0017] Although the following description includes embodiments relating to ultrasound imaging, these embodiments may also be implemented in other medical imaging systems that employ devices such as ultrasound and/or interventional probes during imaging. These systems, for example, may include magnetic resonance imaging (MRI) systems, computed-tomography (CT) systems, and systems that monitor targeted drug and gene delivery. Further, these medical imaging systems may be used for accurate diagnosis and staging of coronary artery disease and monitoring of therapies including high-intensity focused ultrasound (HIFU), radiofrequency ablation (RFA), and brachytherapy. An exemplary environment that is suitable for practising various implementations of the present system is described in the following sections with reference to FIG. **1**.

[0018] FIG. **1** illustrates an ultrasound system **100** for imaging a target volume **101** in biological tissues of interest in a subject. In one example, the target volume **101** may include cardiac tissues, liver tissues, breast tissues, prostate tissues, thyroid tissues, lymph nodes, vascular structures adipose tissue, muscular tissue, and/or blood cells. Alternatively, the system **100** may be employed for imaging non-biological materials such as manufactured parts, plastics, aerospace composites, and/or foreign objects within a body such as a catheter or a needle. In one embodiment, the ultrasound system **100** may be a console system or a cart-based system. Alternatively, the ultrasound system **100** may be a portable system, such as a hand-held, laptop-style and/or a smartphone-based system. For ease of description, the ultrasound system **100** is represented as a portable ultrasound system.

[0019] In certain embodiments, the system **100** includes an acquisition subsystem **103** and a processing subsystem **105**. The acquisition subsystem **103** is configured to obtain image data corresponding to the target volume **101**. Further, the processing subsystem **105** is configured to process the acquired image data to generate one or more images corresponding to the target volume **101** in the object of interest. The acquisition subsystem **103** includes transmit circuitry **102**, receive circuitry **110**, and a beamformer **112**. The processing subsystem **105** includes a processing unit **114**, a memory device **118**, and input-output devices **120**.

[0020] In a presently contemplated configuration, the transmit circuitry **102** generates a pulsed waveform to drive an acoustic array **104** housed within a transducer probe **108**. In accordance with embodiments of the present specification, the transducer probe **108** includes an electrical standoff to reduce a footprint of the transducer probe **108**. Particularly, the pulsed waveform drives acoustic elements **106** in the acoustic array **104** to transmit ultrasonic pulses into the target volume **101**. The acoustic elements **106**, for example, may include piezoelectric, piezoceramic, capacitive, and/or microfabricated crystals. At least a portion of the ultrasonic pulses generated by the acoustic elements **106** is backscattered from the target volume **101** to produce echoes that return to the acoustic array **104** and are received by receive circuitry **110** for further processing. It may be noted that the terms "ultrasonic" and "ultrasound" may be used interchangeably in the following description.

[0021] Also, in the embodiment illustrated in FIG. **1**, the receive circuitry **110** is coupled to a beamformer **112** that processes the received echoes and outputs corresponding radio frequency (RF) signals. Subsequently, a processing unit **114** receives and processes the RF signals in near real-time and/or offline mode. The processing unit **114** includes devices such as one or more general-purpose or application-specific processors, digital signal processors, microcomputers, microcontrollers, application specific integrated circuits (ASICs), field programmable gate arrays (FPGA), or other suitable devices in communication with other components of the system **100**. It may be noted that the various components of the ultrasound system **100** are communicatively coupled via a communication channel **124**.

[0022] In addition to receiving and processing the RF signals, in certain embodiments, the processing unit **114** also provides control and timing signals for configuring one or more imaging parameters for imaging the target volume **101** in the subject. Furthermore, in one embodiment, the processing unit **114** stores the delivery sequence, frequency, time delay, and/or beam intensity, for example, in a memory device **118** for use in imaging the target volume **101**. The memory device **118** includes storage devices such as a random access memory, a read only memory, a disc drive, solid-state memory device, and/or a flash memory. In one embodiment, the processing unit **114** uses the stored information for configuring the acoustic elements **106** to direct one or more groups of pulse sequences toward the target volume **101**. Subsequently, the processing unit **114** tracks displacements in the target volume **101** caused in response to the incident pulses to determine corresponding tissue characteristics. The displacements and tissues characteristics, thus determined, may be stored in the memory device **118**. The displacements and tissues characteristics may also be communicated to a medical practitioner, such as a radiologist, for further diagnosis.

[0023] In some embodiments, the processing unit **114** may be further coupled to one or more user input-output devices **120** for receiving commands and inputs from an operator, such as the medical practitioner. The input-output devices **120**, for example, may include devices such as a keyboard, a touchscreen, a microphone, a mouse, a control panel, a display device **122**, a foot switch, a hand switch, and/or a button. In one embodiment, the processing unit **114** processes the RF signal data to prepare image frames and to generate the requested medically relevant information based on user input. Particularly, the processing unit **114** may be configured to process the RF signal data to generate two-dimensional (2D) and/or three-dimensional (3D) datasets corresponding to different imaging modes.

[0024] Further, the processing unit **114** may be configured to reconstruct desired images from the 2D or 3D datasets. Subsequently, the processing unit **114** may be configured to display the desired images on the associated display device **122** that may be communicatively coupled to the processing unit **114**. The display device **122**, for example, may be a local device. Alternatively, in one embodiment, the display device **122** may be remotely located to allow a remotely located medical practitioner to access the reconstructed images and/or medically relevant information corresponding to the target volume **101** in the subject/patient.

[0025] Referring to FIG. **2**, a diagrammatical representation of an exemplary transducer probe **200** having an electrical standoff, in accordance with aspects of the present specification, is depicted. The transducer probe **200** is representative of one embodiment of the ultrasound transducer probe **108** of FIG. **1**. The ultrasound transducer probe **200** is described with reference to the components in FIG. **1**. It may be noted that the terms "ultrasound transducer probe" and "transducer probe" may be used interchangeably. The transducer probe **200** includes a housing **202** and a probe cable **204** coupled to the housing **202**. The housing **202** may have one or more desired shapes depending upon the target volume **101** (see FIG. **1**) in a subject/body that may be scanned using the transducer probe **200**.

[0026] Further, the housing **202** may have a probe surface **206** at a first end **207** and an opening **208** at a second end **209** of the housing **202**. The probe surface **206** may be a smooth closed surface that is configured to be in physical contact with the subject being scanned. In one example, the probe surface **206** may be formed using one or more materials that are used to provide mechanical protection at the first end **207** of the housing **202**. In another example, the probe surface **206** may be formed using a smooth curved material that acts as a lens in the transducer probe **200**.

[0027] In addition, the probe surface **206** may be configured to allow optimal positioning of the transducer probe **200** on surfaces, such as the chest, breast, and/or abdominal regions of a patient. Further, the opening **208** at the second end **209** of the housing **202** is configured to receive at least a portion of the probe cable **204** that is coupled to the housing **202**, as depicted in FIG. **2**. In one example, the probe surface **206** may have sides **236** that may be configured to act as sides of the housing **202**.

[0028] In addition to the housing **202** and the probe cable **204**, the transducer probe **200** includes an acoustic array **210**, a flex interconnect **212**, a sub-cable **214**, and one or more application specific integrated circuit (ASIC) **216**. It may be noted that the transducer probe **200** may include other components, and is not limited to the components shown in FIG. **2**. The acoustic array **210** is disposed adjacent the probe surface **206** of the housing **202**. In the embodiment of FIG. **2**, the acoustic array **210** includes a plurality of acoustic elements **226**, where adjacently disposed acoustic elements **226** of the plurality of acoustic elements **226** are separated by a gap **240**.

[0029] Further, these acoustic elements **226** are arranged to form an array aperture **227** adjacent the probe surface **206** of the transducer probe **200**. The array aperture **227** may have a lateral size **228**. In one example, the lateral size **228** of the array aperture **227** is same as a lateral size of the acoustic array **210**. Also, these acoustic elements **226** are used to transmit ultrasound signals towards the target volume **101** in the subject via the array aperture **227**. In one example, the acoustic elements **226** may include a piezoelectric layer that is driven by electrical pulses to transmit the ultrasound signals towards the target volume **101**. It may be noted that the number of acoustic elements **226** included in the acoustic array **210** may vary depending upon the transducer design and/or type of imaging that is to be performed.

[0030] Further, the flex interconnect **212** may include interconnects that are flexible and adaptable to provide electrical connection between the acoustic array **210**, the ASIC **216**, and one or more electronic units **252** in the probe **200**. Further, the one or more electronic units **252** may be electrically coupled to the probe cable **204** via the sub-cable **214**. The flex interconnect **212** is configured to electrically couple the acoustic array **210** to the electronic units **252**. In one example, the flex interconnect **212** may be used to communicate the ultrasonic/electrical pulses between the piezoelectric layer in the acoustic elements **226** and the electronic units **252** in the probe **200**. In one embodiment, the electronic units **252** may be positioned outside the transducer probe **200**.

[0031] Further, the ASIC **216** is positioned adjacent the flex interconnect **212** to receive one or more ultrasound signals that are reflected from the target volume **101** in the subject. Also, the ASIC **216** may process and communicate these reflected ultrasound signals to the electronic units **252**.

[0032] In addition, the ASIC **216** may include one or more input-output (I/O) connections **250** disposed along a periphery of the ASIC **216**, as depicted in FIG. **2**. In one example, the I/O connections **250** are routed along the flex interconnect **212**. In one embodiment, these I/O connections **250** may be used for electrically coupling the ASIC **216** to the processing unit **114** for communicating the ultrasound signals to the processing unit **114**. Also, due to the presence of the I/O connections **250** at the periphery of the ASIC **216**, a lateral size **254** of the ASIC **216** and the flex interconnect **212** are extended beyond the lateral size **228** of the array aperture **227**. Further, it is desirable for the flex interconnect **212** to maintain a minimum bending radius to avoid failures due to trace breakage of the flex interconnect **212**. Thus, it is desirable for the housing **202** of the transducer probe **200** to extend such that the housing **202** covers these components of the transducer probe **200**.

[0033] Existing probes may include a stacked structure consisting of an acoustic array, an interconnect, and and one or more ASICs. Also, this stacked structure is positioned adjacent a probe surface of the transducer probe. Further, a lateral size of the ASICs and a lateral size of the interconnect are substantially larger than a lateral size of the acoustic stack in the transducer probe. As a result, a footprint of the transducer probe extends beyond the lateral size of the acoustic stack. As will be appreciated, a transducer probe with such a large footprint is particularly undesirable in applications where the transducer probe needs to be maneuvered in relatively small spaces.

[0034] In accordance with aspects of the present specification, the exemplary transducer probe **200** is configured to overcome the above shortcomings. In particular, the exemplary transducer probe **200** may employ an electrical standoff **230** to reduce a footprint **232** of the transducer probe **200** to a first value. In one example, the first value is proximate to a lateral size **228** of the array aperture **227**. The footprint **232** may be representative of an outer width of the transducer probe **200** at a determined depth **234** from the probe surface **206**. In one example, the determined depth **234** is in a range from about 1 mm to about 4 mm.

[0035] As depicted in FIG. **2**, the electrical standoff **230** may be positioned between the flex interconnect **212** and the acoustic array **210** to distance the acoustic array **210** from the flex interconnect **212**. In one example, by positioning the electrical standoff **230** between the flex interconnect **212** and the acoustic array **210**, the flex interconnect **212** may be positioned away from the probe surface **206** and the acoustic array **210**. This in turn provides spacing within the housing **202** and allows the sides **236** of the probe surface **206** to be positioned closer to the acoustic array **210**. As one or more of the sides **236** of the probe surface **206** are positioned closer to the acoustic array **210**, the footprint **232** of the transducer probe **200** is reduced to the first value. In one example, the first value may relatively closely match with the lateral size **228** or be proximate to the lateral size **228** of the array aperture **227**. In a non-limiting example, the footprint **232** of the exemplary transducer probe **200** is in a range from about 23 mm to about 35 mm. Advantageously, the footprint **232** of the transducer probe **200** is reduced without minimizing the array aperture **227** of the acoustic array **210**.

[0036] In the embodiment of FIG. **2**, the electrical standoff **230** may include a plurality of standoff elements **238**, where adjacently disposed standoff elements **238** of the plurality of standoff elements are separated by corresponding gaps **242**. In one embodiment, the gaps **242** may be vertical gaps and/or slanted gaps. Further, the gaps **242** may be of any desired shape. Advantageously, the slanted gaps between the standoff elements **238** may aid in improving an acoustic performance of the probe **200**. By way of example, the slanted gaps between the standoff elements **238** may cause the ultrasound signals that travel in the electrical standoff **230** to encounter more interfaces, which in turn increases propagation distance and absorption of the ultrasound signals in the electrical standoff **230**. In one example, these ultrasound signals may be undesirable acoustic signals that are transmitted by the acoustic array **210** towards the flex interconnect **212** and the ASIC **216**.

[0037] Further, the standoff elements **238** may be fabricated from one or more electrical and thermal conductors. In one embodiment, the gaps **242** may be filled with one or more electrical insulators to isolate the standoff elements **238** from one another. Also, each of these standoff elements **238** may be aligned with a corresponding acoustic element in the acoustic array **210**. In one example, each of the standoff elements **238** may be electrically coupled to at least one of the acoustic elements **226** in the acoustic array **210**.

[0038] Furthermore, the flex interconnect **212** may include a plurality of pass-through connections **244**. The pass-through connections **244** are used for electrically coupling the one or more standoff elements **238** in the electrical standoff **230** to the ASIC **216**. In one embodiment, each of these pass-through connections **244** may be aligned with a corresponding standoff element **238** in the electrical standoff **230**. In one embodiment, the ASIC **216** may include one or more ASIC bumps **248** that are used to electrically couple the ASIC **216** to the standoff elements **238** via the pass-through connections **244**. Thus, the ASIC **216** is electrically coupled to the acoustic elements **226** in the acoustic array **210** through the ASIC bumps **248**, the pass-through connections **244**, and the standoff elements **238**.

[0039] In an exemplary embodiment, the electrical standoff **230** may be used to attenuate at least a portion of the ultrasound signals transmitted towards the flex interconnect **212**. Particularly, while transmitting the ultrasound signals towards the target volume, the acoustic elements **226** may transmit a portion of the ultrasound signals towards the flex interconnect **212** and the ASIC **216** in the ultrasound probe **200**. These ultrasound signals may cause spurious reflections with the ultrasound signals received from the target volume **101**. As a result, image artifacts may be obtained in an ultrasound image of the target volume **101**. To avoid these problems, the standoff elements **238** in the electrical standoff **230** are used to absorb the ultrasound signals transmitted by the acoustic elements **226** towards the flex interconnect **212**. This in turn prevents spurious reflections in the transducer probe **200**.

[0040] In addition, the electrical standoff **230** may be used to manage heat generated in the ultrasound probe **200**. In one example, the ASIC **216** may generate heat while processing the ultrasound signals received from the target volume **101**. However, this heat may propagate towards the probe surface/lens **206** and may cause the probe **200** to overheat, which in turn may deactivate/shutdown the probe **200**. To avoid this problem, the standoff elements **238** may include one or more low thermal conductive materials to thermally isolate the lens/probe surface **206** from the ASIC **216**, which in turn prevents heating of the lens/probe surface **206**. In another embodiment, the electrical standoff **230** may be used to remove heat generated by the acoustic array **210** and the lens/probe surface **206**. Particularly, the electrical standoff **230** may provide a thermal path for the heat generated by the acoustic array **210** to propagate towards the ASIC **216**, or any other thermal management components in the transducer probe **200**.

[0041] Also, in one embodiment, the electrical standoff **230** may include a low parasitic capacitance that allows for reduced power consumption during transmission of the ultrasonic/electrical pulses to the acoustic elements **226** in the acoustic array **210**. Further, this low parasitic capacitance may reduce noise while receiving the ultrasound signals from the target volume **101**.

[0042] Thus, by employing the electrical standoff **230** in the ultrasound transducer probe **200**, the footprint **232** of the transducer probe **200** is reduced to more closely match with the array aperture **227** of the acoustic array **210**. Also, the footprint **232** of the transducer probe **200** is reduced without minimizing the array aperture **227** of the acoustic array **210**. Furthermore, the electrical standoff **230** may aid in attenuating the ultrasound signals transmitted by the acoustic array **210**, which in turn reduces spurious reflections in the ultrasound probe **200**. In addition, the electrical standoff **230** may aid in managing the heat generated in the ultrasound probe **200**.

[0043] FIG. **3** is a diagrammatical representation **300** of a comparison of a portion of an exemplary transducer probe **302** with a portion of a conventional transducer probe **304**. The exemplary transducer probe **302** is similar to the transducer probe **200** of FIG. **2**. Reference numeral **306** represents a footprint of the transducer probe **302**. The footprint **306** is determined at a depth **308** from a probe surface **322**. Reference numeral **310** represents a footprint of the transducer probe **304** at the same depth **308** from a probe surface **324**.

[0044] Further, the exemplary transducer probe **302** and the conventional transducer probe **304** are illustrated at a same scale and are symmetrically positioned along a vertical axis **314**, as depicted in FIG. **3**. By positioning an electrical standoff **316** between an acoustic array **318** and a flex interconnect **320** in the exemplary transducer probe **302**, the acoustic array **318** may be distanced from the flex interconnect **320**. This in turn provides spacing within a housing of the transducer probe **302** and allows sides of the probe surface **322** to be positioned closer to the acoustic array **318**. As a result, the footprint **306** of the exemplary transducer probe **302** is reduced to a size lower than that of the footprint **310** of the conventional transducer probe **304**, as depicted in FIG. **3**. In one example, the footprint **306** of the exemplary transducer probe **302** may be reduced by about 4 mm as compared to the footprint **310** of the conventional transducer probe **304**. Also, the footprint **306** may more closely match with an array aperture of the acoustic array **318**, thereby enabling the probe **302** to be maneuvered in smaller spaces.

[0045] Referring to FIG. **4**, a diagrammatical representation **400** of a first interposer **402** coupled to an electrical standoff **404**, in accordance with aspects of the present specification, is depicted. The electrical standoff **404** is similar to the electrical standoff **230** of FIG. **2**. In particular, the electrical standoff **404** includes one or more standoff elements **406** that are separated from one another by insulators **408**. In one example, the standoff elements **406** may include one or more conductive materials, while the insulators **408** may include one or more insulating materials. Further, the electrical standoff **404** may have a first pitch **410**. As used herein, the term “pitch” refers to a distance from the center of one element to the center of an adjacent element. In one example, these elements may be insulators in the electrical standoff, ASIC bumps in an ASIC, acoustic elements in an acoustic array, or pass-through connections in a flex interconnect. As illustrated in FIG. **4**, the first pitch **410** may be representative of a distance from the center of one spacing/insulator **408** to the center of an adjacent spacing/insulator **408** in the electrical standoff **404**.

[0046] In a similar manner, ASIC bumps **412** that are coupled to an ASIC (shown in FIG. **2**) may have a second pitch **414**. The second pitch **414** may be representative of a distance from the center of one ASIC bump **412** to the center of an adjacent ASIC bump **412**. In some embodiments, the second pitch **414** of the ASIC bumps **412** may be different from the first pitch **410** of the electrical standoff **404**. In one example, if the second pitch **414** of the ASIC bumps **412** is ‘x’ then the first pitch **410** of the electrical standoff **404** is ‘x+y,’ where ‘y’ is additional distance/pitch. As a result, each of the ASIC bumps **412** may not be electrically coupled to a corresponding standoff element **406** in the electrical standoff **404** when the electrical standoff **404** is positioned in the transducer probe. This in turn may affect an ultrasound imaging of a target volume in a subject.

[0047] In certain embodiments, the first interposer **402** is positioned between the electrical standoff **404** and the ASIC bumps **412** to facilitate coupling between the electrical standoff **404** and the ASIC bumps **412**. In particular, the first interposer **402** is used to electrically couple the electrical standoff **404** having the first pitch **410** to the ASIC bumps **412** having the second pitch **414**. In one example, the first interposer **402** may include a plurality of electrical lines **416** that facilitate connecting each of the ASIC bumps **412** with a corresponding standoff element **406** in the electrical standoff **404**, as depicted in FIG. **4**. In one embodiment, the electrical standoff **404** may have slanted gaps between the standoff elements **406**. In one example, these slanted gaps may be filled with insulators, such as tungsten-epoxy composites to improve attenuation of the ultrasound signals. Further, the slanted gaps between the standoff elements **406** may change a pitch of the electrical standoff **404**. Even in this embodiment, the first interposer **402** may be coupled/integrated with the electrical standoff **404** to facilitate electrical connection between the standoff elements **406** having the slanted gaps and the ASIC bumps **412**. Thus, by employing the first interposer **402**, the electrical standoff **404** may be electrically coupled to the ASIC bumps **412** even if the electrical standoff **404** and the ASIC bumps **412** have different pitches. In the embodiment of FIG. **4**, a flex interconnect (see flex interconnect **212** of FIG. **2**) may not be used between the electrical standoff **404** and the ASIC bumps **412**. Particularly, the electrical standoff **404** may be coupled to the ASIC bumps **412** without using the flex interconnect.

[0048] Referring now to FIG. **5**, a diagrammatical representation **500** of a first interposer **502** coupled to an electrical standoff **504**, in accordance with one embodiment of the present specification, is depicted. The embodiment of FIG. **5** is similar to the embodiment of FIG. **4** except that a flex interconnect **506** is positioned between the electrical standoff **504** and ASIC bumps **508**. Further, the first interposer **502** is positioned between the electrical standoff **504** and the flex interconnect **506**. The flex interconnect **506** is similar to the flex interconnect **212** of FIG. **1**. Also, the first interposer **502** is similar to the first interposer **402** of FIG. **4**.

[0049] As depicted in FIG. **5**, the ASIC bumps **508** may be coupled to pass-through connections **510** of the flex interconnect **506**. Further, the electrical standoff **504** may have a first pitch **512**, while the flex interconnect **506** may have a second pitch **514** that is different from the first pitch **512** of the electrical standoff **504**. In one example, the first pitch **512** may be similar to the first pitch **410** of FIG. **4**. Further, the second pitch **514** of the flex interconnect **506** may be representative of a distance from the center of one pass-through connection **510** to the center of an adjacent pass-through connection **510** of the flex interconnect **506**.

[0050] In certain embodiments, the first interposer **502** is used to electrically couple the electrical standoff **504** having the first pitch **512** to the pass-through connections **510** of the flex interconnect **506** having the second pitch **514**. In one example, the first interposer **502** may include a plurality of electrical lines **516** that facilitate connecting each of the pass-through connections **510** with a corresponding standoff element **518** of the electrical standoff **504**, as depicted in FIG. **5**. Thus, by employing the first interposer **502**, the electrical standoff **504** may be electrically coupled to the flex interconnect **506** even if the electrical standoff **504** and the flex interconnect **506** have different pitches.

[0051] Referring now to FIG. **6**, a diagrammatical representation **600** of a second interposer **602** coupled to an electrical standoff **604**, in accordance with aspects of the present specification, is depicted. The second interposer **602** is similar to the first interposer **402** of FIG. **4**. However, the second interposer **602** is positioned between an electrical standoff **604** and an acoustic array **606**. Also, the second interposer **602** is used to electrically couple the electrical standoff **604** having a first pitch **608** to the acoustic array **606** having a second pitch **610**. The first pitch **608** of the electrical standoff **604** is different from the second pitch **610** of the acoustic array **606**. Also, in one example, the second pitch **610** of the acoustic array **606** may be representative of a distance from the center of one acoustic element **612** to the center of an adjacent acoustic element **612** in the acoustic array **606**.

[0052] Advantageously, as illustrated in the embodiment of FIG. **6**, the second interposer **602** is used to electrically couple the electrical standoff **604** having the first pitch **608** to the acoustic array **606** having the second pitch **610**, where the first pitch **608** is different from the second pitch **610**.

[0053] Although not illustrated, various other embodiments are envisioned. By way of example, in one embodiment, the first interposer may be positioned between the electrical standoff and the flex interconnect or the ASIC bumps. Further, in the same embodiment, the second interposer may be positioned between the electrical standoff and the acoustic array.

[0054] Referring to FIG. **7**, a diagrammatical representation **700** of a portion of an exemplary transducer probe having an electrical standoff, in accordance with one embodiment of the present specification, is depicted. Reference numeral **702** represents a transducer probe, while reference numeral **704** represents a flex interconnect. The transducer probe **702** is similar to the transducer probe **200** of FIG. **2**. However, in the transducer probe **702**, the flex interconnect **704** is coupled only to input-output (I/O) connections **250** on the ASIC **216**. Particularly, in the example of FIG. **7**, the flex interconnect **704** is not positioned between the ASIC bumps **248** and the electrical standoff **230**. Consequently, the standoff elements **238** of the electrical standoff **230** may be directly coupled to the ASIC bumps **248** without using pass-through connections of the flex interconnect **704**.

[0055] Referring now to FIGS. **8-10**, diagrammatical representation of different embodiments of an electrical standoff, in accordance with aspects of the present specification, is depicted. It may be noted that the electrical standoff depicted in FIGS. **8-10** may be similar to the electrical standoff **230** of FIG. **2**.

[0056] In the embodiment of FIG. **8**, an electrical standoff **800** includes standoff elements **802** that are separated by vertical gaps **804**. In one example, the vertical gaps **804** may be filled with one or more insulators. Also, the standoff elements **802** may act as straight conductors to communicate signals from one or more ASICs to an acoustic array (see FIG. **2**).

[0057] In the embodiment of FIG. **9**, an electrical standoff **900** includes standoff elements **902** that are separated by slanted gaps **904**. In one example, the slanted gaps **904** may be filled with one or more insulators. Also, the standoff elements **902** may act as slanted conductors in the electrical standoff **900** to disrupt ultrasound signals that are transmitted by an acoustic array (see FIG. **2**) towards a flex interconnect and/or an ASIC. Further, the disrupted ultrasound signals may scatter in the electrical standoff **900**, which in turn result in improved attenuation of the ultrasound signals in a probe. Also, in one embodiment, the slanted gaps **904** between the standoff elements **902** may cause the ultrasound signals to encounter more interfaces, which in turn increases propagation distance and absorption of the ultrasound signals in the electrical standoff **900**. As a result, attenuation of the ultrasound signals may be improved in the probe.

[0058] Further, in the embodiment of FIG. **10**, an electrical standoff **1000** includes standoff elements **1002** having an integrated redistribution structure. It may be noted that the integrated redistribution structure may be representative of a structure, where one or more of the standoff elements **1002** may converge with respect to one another from a first end **1004** of the electrical standoff **1000** to a second end **1006** of the electrical standoff **1000**, as depicted in FIG. **10**. As a result of this integrated redistribution structure, the electrical standoff **1000** may have a first pitch at the first end **1004** and a second pitch at the second end **1006** of the electrical standoff **1000**, where the first pitch is different from the second pitch. This change in pitches at the first end **1004** and the second end **1006** of the electrical standoff **1000** may aid in electrically coupling the acoustic array to the flex interconnect/ASIC bumps even if the acoustic array and the flex interconnect/ASIC bumps have different pitches. Advantageously, this integrated redistribution structure of the electrical standoff **1000** may facilitate electrical connection between the acoustic stack and the flex interconnect/ASIC without using an interposer. Furthermore, in one embodiment, the electrical standoffs **800**, **900**, **1000** depicted in FIGS. **8-10** may be printed by using a three dimensional (3D) printer.

[0059] The various embodiments of the exemplary system aid in reducing the footprint of the transducer probe without minimizing the array aperture of the acoustic array. Also, the footprint of the transducer probe is more closely matched with the array aperture of the acoustic array. In addition, the ultrasound signals transmitted by the acoustic array towards the flex interconnect are attenuated to minimize spurious reflections in the transducer probe. Moreover, the heat generated in the transducer probe may be conducted away from the lens/probe surface, or prevented from being conducted towards the lens/probe surface, which in turn prevents the acoustic array and the lens/probe surface from overheating during operation of the ultrasound probe.

[0060] While only certain features of the present disclosure have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the present disclosure.

1. A transducer probe, comprising:

a housing having a probe surface at a first end;

an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume;

a flex interconnect configured to electrically couple the acoustic array to at least one electronic unit; and

an electrical standoff disposed between the acoustic array and the flex interconnect to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array aperture.

2. The transducer probe of claim **1**, wherein the electrical standoff is configured to distance the acoustic array from the flex interconnect to reduce the footprint of the transducer probe.

3. The transducer probe of claim **1**, wherein the acoustic array comprises a plurality of acoustic elements, and wherein adjacently disposed acoustic elements of the plurality of acoustic elements are separated by a gap.

4. The transducer probe of claim **3**, wherein each of the plurality of standoff elements is electrically coupled to at least one acoustic element of the plurality of acoustic elements.

5. The transducer probe of claim **4**, wherein the flex interconnect comprises a plurality of pass-through connections, and wherein each pass-through connection of the plurality of pass-through connections is aligned with a corresponding standoff element of the plurality of standoff elements.

6. The transducer probe of claim **5**, further comprising at least one application specific integrated circuit (ASIC) electrically coupled to one or more of the plurality of standoff elements and configured to process the ultrasound signals received from the target volume.

7. The transducer probe of claim **6**, wherein the at least one ASIC comprises a plurality of ASIC bumps configured to electrically couple at least a portion of the ASIC to the plurality of standoff elements via the pass-through connections in the flex interconnect.

8. The transducer probe of claim **6**, further comprising one or more input-output (I/O) connections disposed along a periphery of the ASIC, wherein the one or more input-output connections are routed along a length of the flex interconnect.

9. The transducer probe of claim **1**, further comprising a first interposer disposed between the electrical standoff and the flex interconnect and configured to electrically couple the electrical standoff to the flex interconnect, and wherein a pitch of the electrical standoff is different from a pitch of the flex interconnect.

10. The transducer probe of claim **1**, further comprising a second interposer disposed between the electrical standoff and the acoustic array and configured to electrically couple the electrical standoff to the acoustic array, wherein a pitch of the electrical standoff is different from a pitch of the acoustic array.

11. The transducer probe of claim **1**, wherein the electrical standoff comprises an integrated redistribution structure configured to electrically couple the acoustic array to the flex interconnect, and wherein a pitch of the acoustic array is different from a pitch of the flex interconnect.

12. A system for ultrasound imaging, the system comprising:

an acquisition subsystem configured to obtain image data corresponding to a target volume in an object of interest and comprising an ultrasound probe, wherein the ultrasound probe comprises:

a housing having a first end and a second end, wherein the first end comprises a probe surface, and wherein the second end is coupled to a probe cable;

an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards the target volume;

a flex interconnect configured to electrically couple the acoustic array to at least one electronic unit;

an electrical standoff disposed between the acoustic array and the flex interconnect to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array aperture; and

a processing subsystem in operative association with the acquisition subsystem and configured to process the acquired image data to generate one or more images corresponding to the target volume in the object of interest.

13. The system of claim **12**, wherein the electrical standoff is configured to distance the acoustic array from the flex interconnect to reduce the footprint of the transducer probe.

14. A transducer probe, comprising:

a housing having a probe surface at a first end;

an acoustic array having an array aperture, wherein the acoustic array is disposed adjacent the probe surface of the housing, and wherein the acoustic array is configured to transmit ultrasound signals towards a target volume;

at least one ASIC configured to electrically couple the acoustic array and configured to receive the ultrasound signals reflected from the target volume; and

an electrical standoff disposed between the acoustic array and the at least one ASIC to reduce a footprint of the transducer probe to a first value, wherein the first value is proximate to a lateral size of the array.

15. The transducer probe of claim **14**, wherein the electrical standoff is configured to distance the acoustic array from the at least one ASIC to reduce the footprint of the transducer probe.

16. The transducer probe of claim **14**, wherein the at least one ASIC comprises at least one input-output connection disposed along a periphery of the at least one ASIC.

17. The transducer probe of claim **16**, further comprising a flex interconnect coupled to the at least one input-output connection and configured to electrically couple the ASIC to one or more electronic units in the transducer probe.

18. The transducer probe of claim **14**, wherein the at least one ASIC comprises a plurality of ASIC bumps configured to electrically couple the at least one ASIC to a plurality of standoff elements in the electrical standoff.

19. The transducer probe of claim **14**, further comprising a first interposer configured to electrically couple the electrical stand off and the ASIC, wherein a pitch of the electrical standoff is different from a pitch of the ASIC.

20. The transducer probe of claim **14**, wherein the electrical standoff comprises an integrated redistribution structure configured to electrically couple the acoustic array to the ASIC, and wherein a pitch of the acoustic array is different from a pitch of the ASIC.

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专利名称(译)	用于减小超声换能器探头的占地面积的系统		
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摘要(译)

提出了一种换能器探头。换能器探头包括壳体，壳体在第一端具有探针表面。此外，换能器探头包括具有阵列孔的声学阵列，其中声学阵列邻近壳体的探针表面设置，并且其中声学阵列配置成朝向目标体积发射超声信号。而且，换能器探头包括柔性互连件，该柔性互连件被配置为将声学阵列电耦合到至少一个电子单元。此外，换能器探头包括设置在声学阵列和柔性互连之间的电气支座，以将换能器探头的占地面积减小到第一值，其中第一值接近阵列孔径的横向尺寸。